Streamlining the Shaping of Airfoils Using a Laser Engraver

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C-Division

Summary

The objective of this project was to see if it was possible to streamline the airfoiling of balsa wood fins and wings by shaving off most of the wood using a laser engraver. They take a long time to sand, and it you have a lot of fins to airfoil, it can be a daunting task. The advantage of airfoiled fins is that the rocket flies higher due to reduced drag.

There is a process of airfoiling the fins using a laser. There are some computer files that have to be made first. But they are drawing images that can be made using common software, and don't require CAD skills.

The main objective of these computer files is to control the color gradient. The color controls the power of the laser beam. Dark colors, like black, tell the laser to use full power, while lighter colors are lower power. The more power used, the deeper the laser beam burns away into the wood.

The result of the process is a piece of wood that has been shaped into a 3D shape. The surface of the wood is charred, but that is easily sanded away. There is less sanding to do than would be necessary using the traditional technique of carving an airfoil.

While most modelers do not have laser engravers, they are plentiful around the world. Most localities have engravers that make trophies and award plaques. These businesses are willing to do this process, because the cost of making a mistake is minimal, and the material is readily available.

The objectives of the work

The objective of this project was to see if I could find a way to streamline the airfoiling of balsa wood fins and wings. They take a long time to sand, and it you have a lot of fins to airfoil, it can be a daunting task. The advantage of airfoiled fins is that the rocket flies higher due to reduced drag.

The background of this project was that we have multiple people in our family flying competition rockets. Getting ready for a big event like NARAM takes up a lot of time. Adding to our workload this year, was that there is tryouts for the FAI team. That pretty much doubled the number of rockets that we had to make. The one saving grace, is that most of the rockets in FAI competition have similar size, and therefore they use common shaped fins. Because of that, I thought it might be possible to streamline the process to take advantage of the common fin shape.

The approach taken

When I got my laser engraver in 2014, I did not realize how many thing it could do. I learned a lot by joining a FaceBook group called Epilog Laser Fans. Participants call themselves: ELFs. I quickly learned of the variety of ways a laser engraver can be used. One of the tricks I discovered was a technique called "3D cutting."

In 3D cutting, the objective is to burn away the wood (or whatever substrate is being cut) to reveal something that has a three dimensional quality to it. It is trying to mimic intricate wood carving but doing it with a beam of light instead of a chisel. Through this technique, I saw some of the beautiful artwork that other ELFs

A 3D sculpture made by burning away excess wood.

were creating.

When I saw this technique, I wondered if it could be applied to model rocketry. My first thought was trying to airfoil fins.

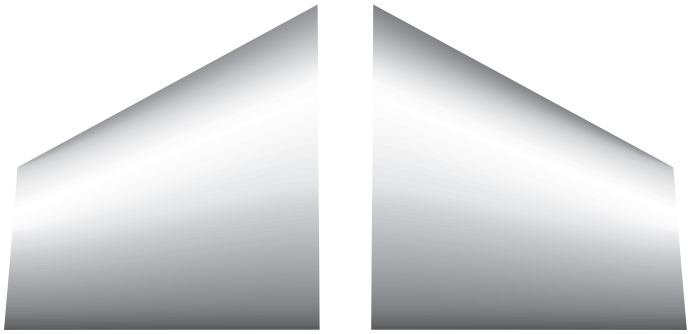
The trick to making 3D artwork, is to control the power of the laser beam, so that it doesn't cut all the way through the wood. You want to control the depth of the cut that the beam of light makes with the laser.

The way this is accomplished, is by a trick of the engraving software that controls the laser engraver. Through the software, the laser's power settings can be controlled by a change of colors. In essence, every color is associated with a different power level in the software, and therefore the power level in the beam.

The way that this is typically used in the engraving industry, is to burn a photographic image onto an award plaque. The process starts by converting a color photographic image into a grey scale image. Each percentage of black is assigned a specific amount of power. Where 100% black is assigned to 100% power from the laser beam, and white is assigned to zero power (the beam doesn't fire).

To make a 3D artwork then, you have to draw a grey scale image that is corresponds to how deep you want the laser to cut into the material.

In the case of a fin or wing, the high point of the airfoil will be a white color, while the trailing edge should be black. And in between, you have a gradual color shift from white to black - which is called a gradient.



In engraving, the darker the color, the more power the laser beam has. The more power, the more material it burns away. An airfoil can be burn away using this technique.

My first attempt to make a airfoil were very encouraging, so I played around with the power settings on the laser to try to refine the final parts. This is where it gets confusing, and you do have to do some tests with the laser.

While the color controls the laser power, you have to still adjust the total power of the laser to the material you are cutting.

The full power of the laser is not used when cutting soft materials. For example, my own laser at Apogee Components is a 75 Watt system. The power can be set anywhere from zero to 75 watts. Some soft materials, like balsa wood don't take the full 75 watts to cut through them. If you are cutting out a fin shape, you might set the power to 20 percent of that full power. If you use too much power, you char the edges of the material, and waste energy. It is not uncommon that fires have been started in a laser cabinet because the power is set to high. You want to use as little power as possible to cut through a material to reduce the risk of fires. In another example, to cut through a body tube, I typically set the power to 3% of the available power.

Additionally, the speed at which the laser head moves over the part being cut will determine how much energy is being focused during the cut. For example, you set the head to move from point A to point B at full speed (as fast as the electric motors can drive it), and very little energy is felt by the material. On the other hand, some materials require a lot of energy to burn through them. For example, when I cut 1/4 inch thick plywood centering rings, I'll set the power level at 100% and have the head move at only 6% of the maximum speed. For cutting paper, you can move the head at 80% speed with a power setting of only 10%.

It should be noted that speed is expressed as a percentage too. I don't know why the laser system manufacturers chose this methodology. It seems to me that inches per second would be more useful. It may be that every machine is different somehow.

The point of this, is that cutting through materials with a laser will be different on every machine. It takes a little experimentation to find how much power and speed to use. If you go to a laser engraver to have fins airfoiled, you'll need to provide extra material so that the laser operator can experiment to find the best balance of power and speed to cut through the material.

The Process of Making an Airfoiled Fin

Step 1: Draw the fin shape in vector format.

The laser cuts two different ways: vector format, or raster format. For airfoiling fins, both methods are used.

Vector format is simple to understand. It is mathematical in nature: start at point A, and go to point B. In other works it is a "line." The line can be straight or curved. But the color stays the same along the line, and therefore the power level to the laser stays the same too.

Raster format is an image that is made up of pixels. Each pixel is separate, and has its own color. Therefore, each pixel is burned with its own power level.

Photographs are always created using raster format.

Lines can be created in raster format, but the laser head moves differently. For example, if the line is diagonally across the page, it doesn't move from one end directly to the other. It only moves horizontally as it cuts, and makes many back-and-forth passes across the diagonal line to cut it. It is very inefficient to cut a diagonal line when in raster format.

It should also be noted that most drawing programs on a computer are not capable of drawing in vector format. After they draw a line, the mathematics is lost, and the line is turned into a series of pixels. Programs like: MS Paint, and photoshop do not save in vector format. They are pixels, so when they output to the laser, they are in raster format.

To make a vector drawing of a fin, you need a program like Adobe Illustrator, Corel Draw, Inkscape (free), or a CAD program. Personally, I use Adobe Illustrator to make my fin drawings, but that is just my preference.

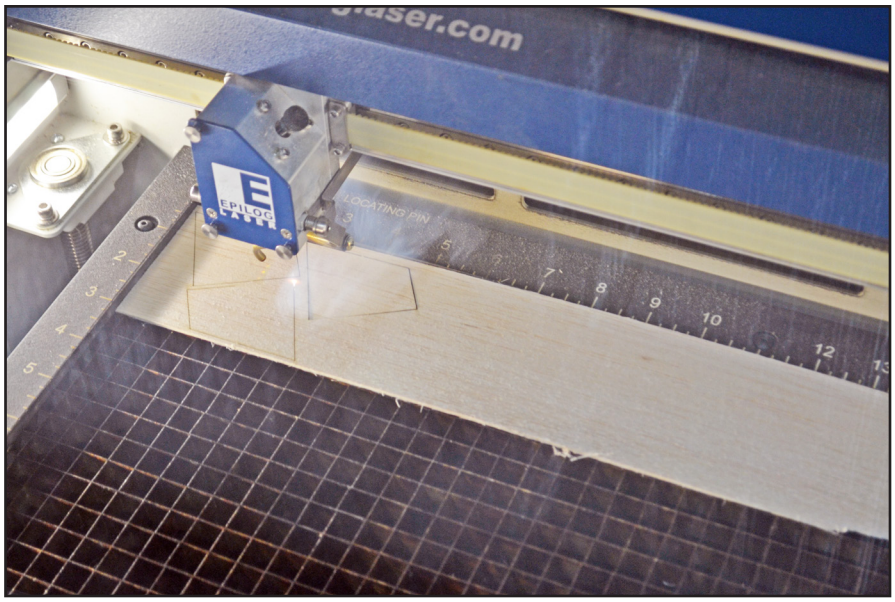
After I make an outline drawing of the fin, I'll orient it so that the grain of the wood will allow for the maximum strength of the fin. I almost always orient the wood on the laser bed, so that the grain runs horizontally rather than vertically.

I'll also duplicate the fin, so that many are cut out from a sheet as possible. I want to maximize the yield of the wood, since it can be pricey.

Step 2: Cut the fins from the material

The next step is to cut out the fins from the material. The settings for the laser are to cut quickly and cleaning through the material.

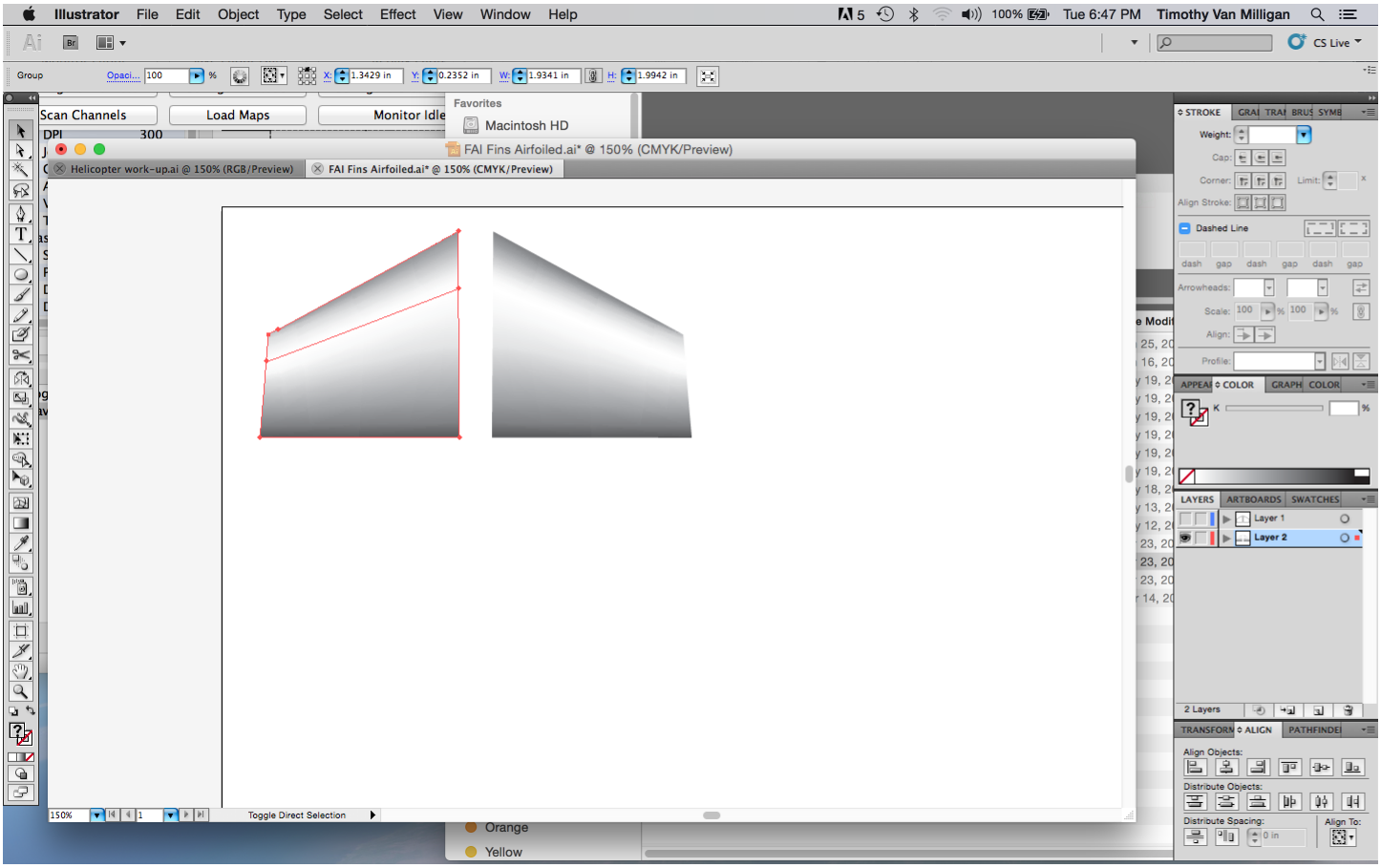
After cutting the fins from the material, the fins could be airfoiled using the traditional sandpaper technique.



The laser cutting out the fins from a balsa wood sheet.

Step 3: Create a raster image of what the airfoil should look like.

This is where you have to create the gradient from white to black for the cutting of the airfoil.



A drawing program can allow you to create the color gradient for the fins. In this image, the trailing edge of the fin is oriented horizontally.

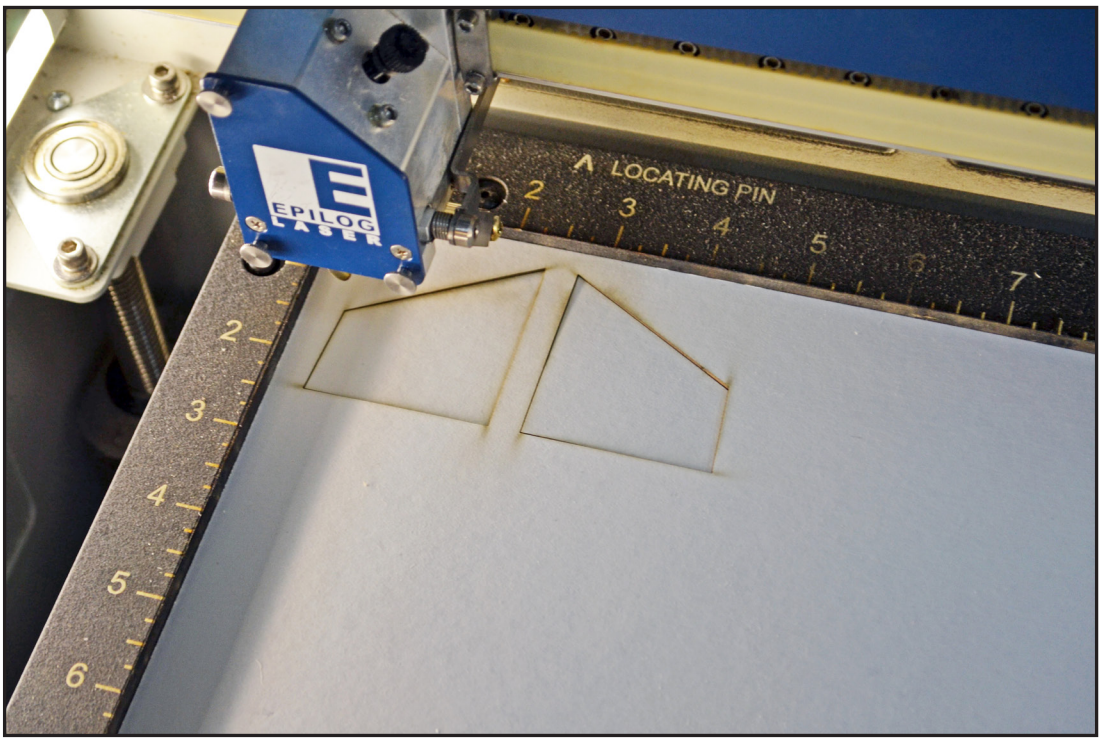
Step 4: Orient the fin to minimize the travel of the laser head as it goes across the material.

Where a typical fin has the leading edge oriented horizontally along the laser bed because the wood grain runs horizontally, that would elongate the distance the head has to travel to make a pass along the fin. I typically orient the fin in the drawing so the trailing edge is horizontal.

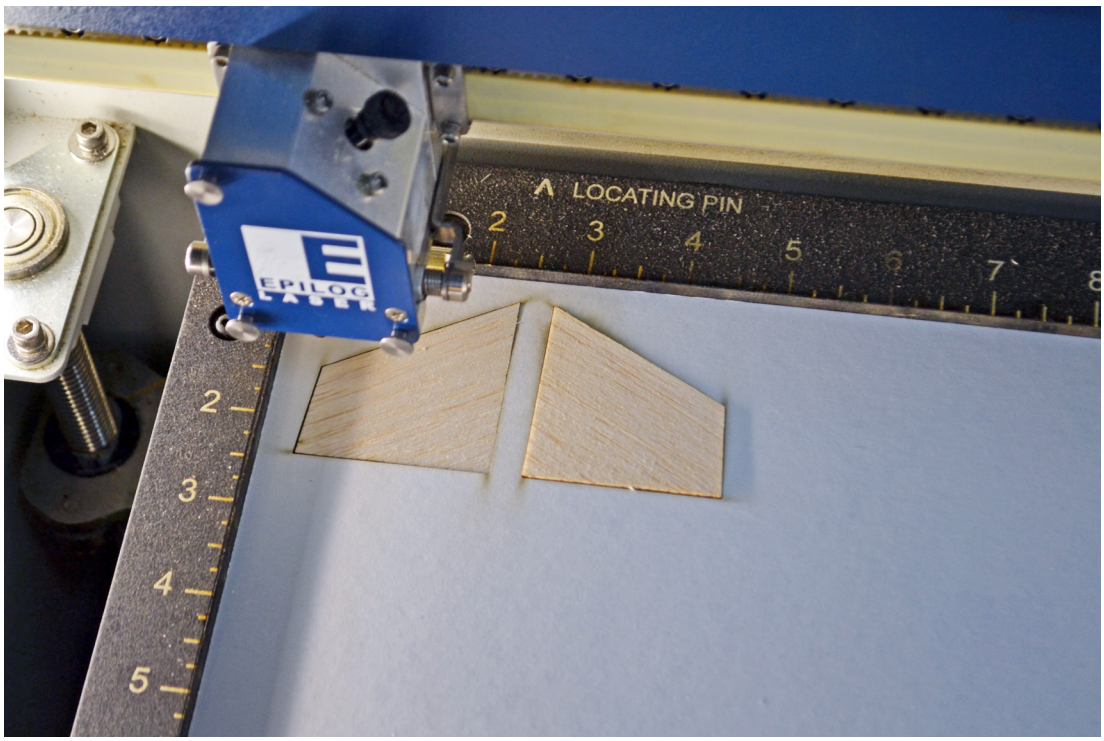
Step 5: Create a mask that will be used to hold the fins in position.

I use a piece of cardboard with a window that will hold the fins in position while the laser passes back and forth to burn away the wood. The cardboard is positioned in the same spot every time a new fin is placed into it. I simply push the cardboard into the top left corner of the machine so it is in the same spot every time.

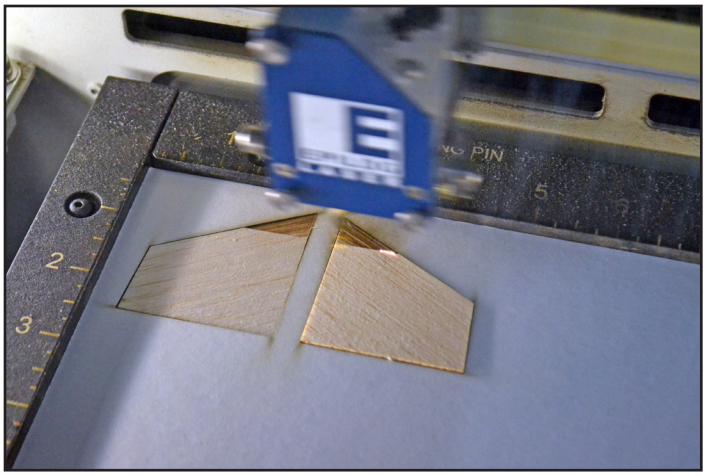
The same vector image that is used to cut the wood blanks can be used to make the mask, although the fin orientation has to be positioned to match the gradient drawing. I typically use layers so that I can move both the vector and the gradient at the same time.



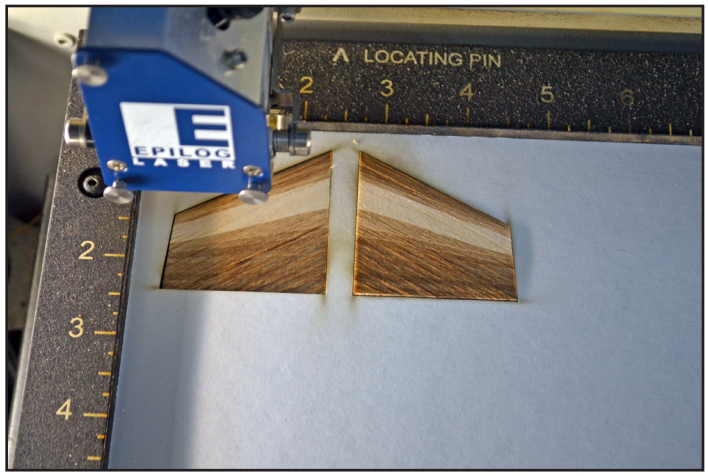
A pattern is cut from a sheet of cardboard. The cardboard will hold the fins in the right location on the table for the cutting process. Two fins will be done at once, one for each size of airfoil.



The fins are placed in the pattern.



The laser head speeds back and forth across the fins and burns the way the wood. The bright area is the wood lighting up as it burns away.



The fins after completion of the burning process. The grain varies in density, so the wood looks very rough at this point.

You also need to duplicate the fin, and flip it over. The reason for this, is because both sides of the fin have to be cut in order to create a symmetrical airfoil.

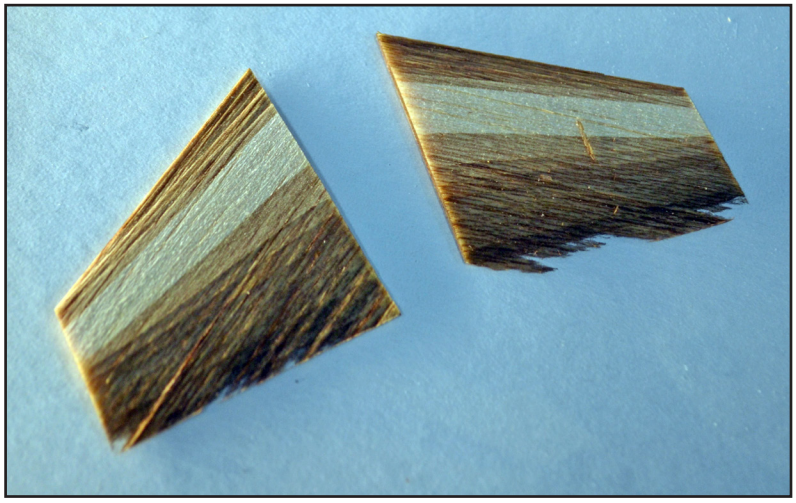
I only do two fins in the mask. The reason is that if I make a mistake with the power settings during the raster burn, that I don't ruin more than two pieces at any time.

Step 5: Testing to adjust the power and speed settings

The first time you start raster cutting the fins, you have to adjust the power and speed settings. You want to have the power and speed so that the areas that are black are cut to 50% of the depth of the wood. I actually want it to go about 40% deep, instead of exactly 50%. The reason is that the cutting process is always going to leave the wood charred. I like to sand through it, so you have to leave some extra wood to sand into. It takes a couple of fins to dial in the right about of power and speed.

The final setting you can make is the number of passes the laser takes to go from the top to the bottom of the fin. This is measured in dots per inch. The higher the dots per inch, the smoother the surface will look. But it also increases the time in the machine. By default, the laser is set at 600 dpi, which means the head has to go back-and-forth 600 times to travel 1 inch downward. I try to run at 300 dpi, but sometime the material is so hard that it takes more passes to burn away enough material.

If you don't have enough power, the solution is to run the material twice through the laser. I don't mind doing this, because it doesn't waste material, and you can see how the material is burning away.



Burning away too much wood leaves the edge ragged. The solution is to increase the speed of the head so it passes quicker over the wood, or by turning the power down.

Step 6: Turn the wood over.

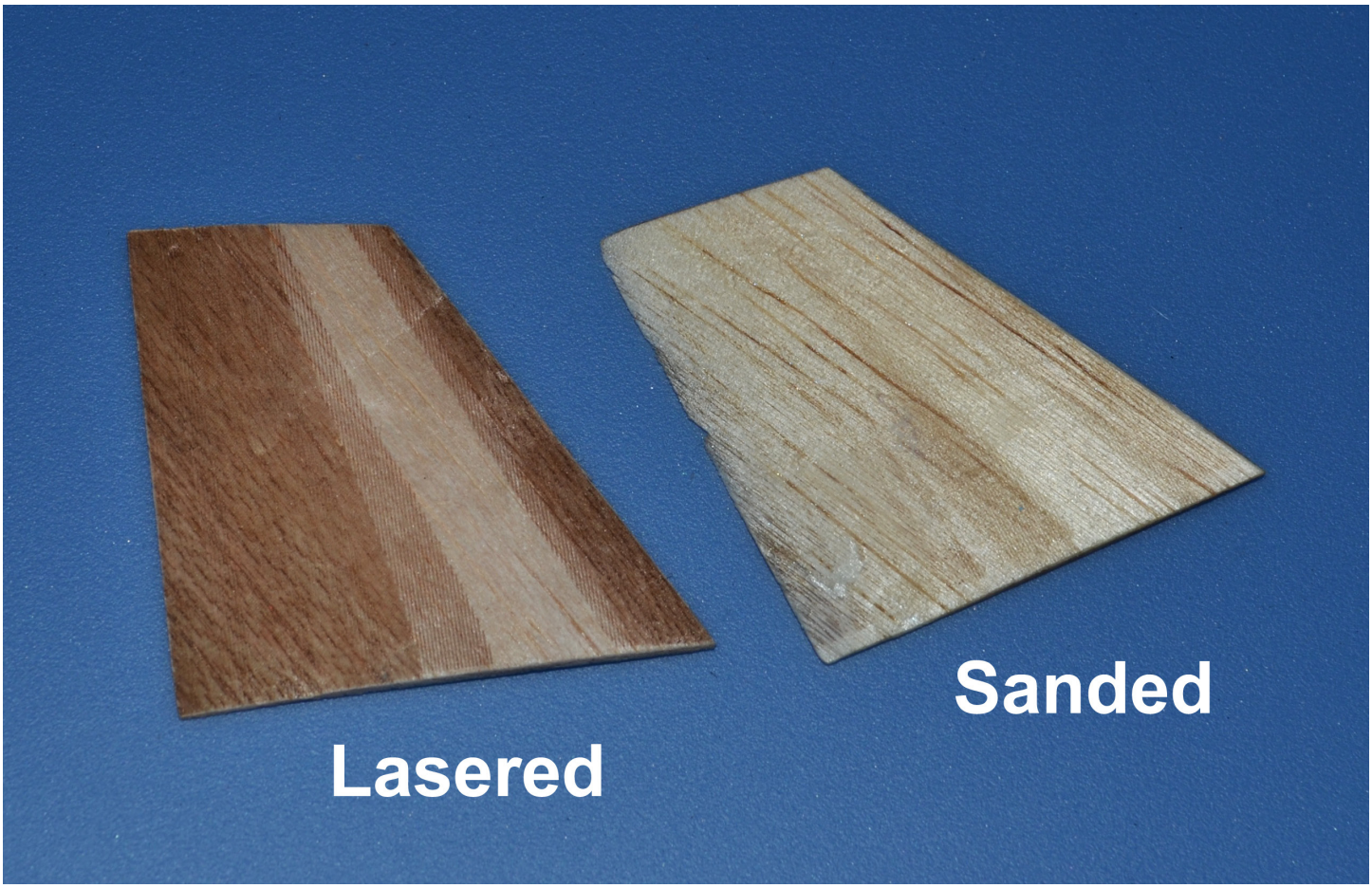
Once one side is cut, the fins have to be flipped over so that the other side can be burned away.

Step 7: Sand off the burnt surfaces

There is some sanding to do once the laser has done its job, the burnt surface still needs to be sanded smooth.

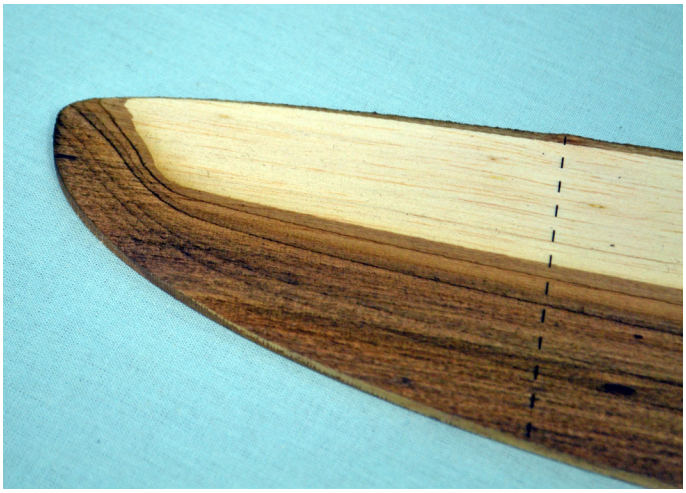
The surface isn't smooth. The reason is that wood has variable density. The harder the wood, the less amount of wood is burned away. So you end up with ridges in the wood, and they happen to follow the wood grain.

But the good news is that it takes a lot less time to sand away the burnt area than it does to sand a typical airfoil.

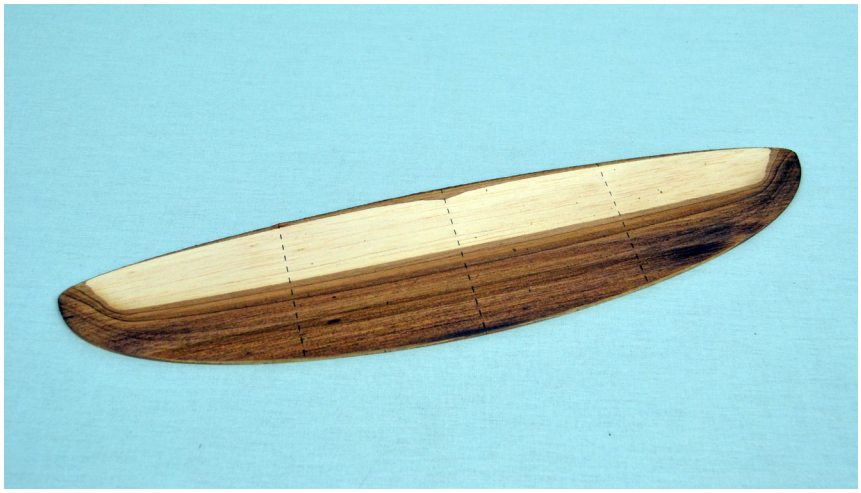


Another Advantages

The other advantage of the laser is that the burnt surfaces show you where exactly to sand. As long as you don't sand into the unburnt area, your fins should come out more uniform than trying to do it the typical way of sanding. This makes is a much easier way for big pieces, like large wings.



The advantage of the laser, is that you can easily tell where you need to sandl



This is the gradient pattern that I used to carve the wing shown above.

List of any related R & D Reports previously entered by the author, if any, with brief summaries

None.

References to previous work done on the subject, found in research preparatory to this report

My research was primarily through the Epilog Laser Fans Facebook group. They gave me the idea for 3D parts.

The equipment used:

I used a 75 watt Epilog CO2 engraver, with a 32" wide by 20" tall bed. For those wishing to replicate this project, the good news is that laser engravers in every community. From my experience with the ELF Facebook group, most laser owners are looking for new jobs to keep their lasers busy. They would be willing to cut fins, because it doesn't take much effort, and mistakes are not expensive.

The facilities used

The laser engraver used is owned and located in the facilities of Apogee Components, Inc.

The money spent on the project (budget)

I spent about $5 on wood for this project. Laser system, should someone be willing to buy one, run anywhere from $6000 and up. The Epilog Laser that I used for this project has a base price of $33,000. The quality of the laser tube is higher than the lower priced models, and typically they last longer.

The data collected

No data collected

The results obtained

The results of this project was that my daughters were able to complete the construction of their FAI models faster because there was less sanding to do. I also have demonstrated that cutting the airfoils with a laser is possible and cost effective.

The conclusions drawn

Cutting the airfoils in fins and wings with a laser can save you time. It does require some planning up front, but the effort is worth it.

Further work that would clarify or extend the results obtained

In the future, I'd like to try to create some under-cambered airfoils. These are more efficient than flat bottom airfoils, but are more difficult to sand.